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Impact of penguin biotransport on the floral landscape of the South Sandwich Islands

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Research Question

To what extent is local flora influenced by ornithogenic soil biochemical-composition in the South Sandwich Islands, with special attention given to Zavodovski, and what are the down-stream effects on the geology of the islands?

Hypothesis

Areas supplied by fluvial run-off from penguin colonies, especially crêches, host the most productive and species rich floral landscapes, even after controlling for geothermal activity.

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https://tinyurl.com/kas028pingu

Keywords biogeochemical linkage · biotransport · floral landscape · penguin colony · south sandwich islands

Introduction

Though the Antarctic and sub-Antarctic are lacking in fauna relative to the other continents, the few creatures that do inhabit the island – Weddell seals, molluscs, and numerous species of penguin—can offer invaluable insight into the ecological makeup of Antarctica. These animals help create an evolving landscape of chemicals that has yet to be studied in great detail. As such, this proposal looks into chinstrap penguin-controlled marine-terrestrial biogeochemical linkage and its influence on local flora.

The study of marine-terrestrial biogeochemical interactions is a highly complex and involved, yet understudied, topic in geo-ecology. Geochemical processes can, in many cases, be the limiting factors in a biological system and so our lack of knowledge is inexcusable. Even despite this dearth of knowledge, it has become clear that there are biogeochemical marine-terrestrial links that play critical roles in the stabilization of chemicals necessary for the perpetuation of local and global ecologies (cf. Ridgwell & Kohfeld 2005).

The volcanic-driven geochemical composition of the South Sandwich Islands is well known (Gass et al. 1963), but it was Ugolini (1972) who was among the first to discover that penguin droppings, which create ornithogenic soils suitable to floral growth, is the most extensive source of organic matter for the terrestrial ecosystems. Subsequent studies (cf. Heine and Speir 1989, Liguang et al. 2004) have demonstrated that penguin excrement has a direct effect on local biomes. Through using geochemical markers, Liguang et al. discovered an inverse relationship between penguin population density and floral growth: after the birds had departed the island, the researchers found floral growth flourished owing to fertile soils. They suggested, then, that a comprehensive population history of local penguins could be recreated using extracted soil cores, an idea further demonstrated in Emslie et al. (2014).

In attempting to demonstrate the causative link between penguin droppings and floral growth, Guo et al. (2018) postulated two mechanisms. First, the moisture content of ornithogenic soils is positively correlated with the number of droppings; in the potentially dry (with respect to precipitation) landscape of Antarctica, increased moisture is crucial. Second, nutrient enrichment occurs due to elevations of carbon, nitrogen, phosphorus, and silicon. The link between penguins and geochemical altercations of local soil was first expressed in Liguang et al. (2004), who used a sulfur, phosphorous, calcium, copper, zinc, selenium, strontium, barium, and fluorine chemical array to infer historical penguin density. Like Guo et al. (2018), the researchers demonstrated that nitrogen and phosphorus were strongly correlated with penguin droppings. However, toxification of the soil can occur in particularly dense colonies, precluding floral growth through both trampling and metal prevalence. For instance, Santamans et al. (2017) showed that penguin droppings promote biotransport of certain chemical pollutants, especially copper, zinc, and selenium, as well as significant amounts of organic carbon. Adjustments to the soil microbiota (e.g dominance of enteric bacteria) was similarly found to have an effect on local flora. As such, Liguang et al. (2004) equivalently shows toxification and heavy metal biotransport occurs during active periods in penguin colonies, which prevents immediate floral growth. The positive effects resulting from penguin presence, namely enhanced moisture content and nutrient enrichment, persists post-departure (or downstream of the colony), which eventually creates a suitable environment for plant growth.

The flora of the Antarctic and sub-Antarctic is much less well-studied. Convey et al. (2000) show that magnitude of geothermal heating is an important factor in floral composition of an area: sub-Antarctic flora can only survive in such places, whereas Antarctic flora is more often found in cooler zones. Other than this, we have very little knowledge of the variables that influence floral composition. This lack of knowledge is especially troublesome given the imminent threat of climate change. Outside of Singh et al. (2018), little literature has explored the relationship between warmer temperatures and Antarctic flora. Examining causative factors behind floral growth – namely biochemical transport – is thereby integral to understanding the uncertain future of Antarctica's plant life, especially given the likelihood of increased fluvial runoff caused by rises in temperature.

It is still not clear to what extent biochemical transport influences the floral landscape of the South Sandwich Islands: this study would discover the nature—or refute the existence—of such a relationship.

Methods

As outlined below, we will dictate four treatments (each with individual n-values of multiple locations). Soil cores would be extracted using a PVC pipe then x-rayed to determine the chemical composition, looking specifically at organic carbon, heavy metals, and phosphates. Using proven fingerprint geochemicals of droppings (see Measurements: 3.), we can infer the relative density of excrement by location and, by extension, how far the droppings are transported fluvially. These results would finally be cross-referenced with floral density at each treatment to create a quantifiable relationship between inferred dropping prevalence (using geochemical profiling as a proxy) and floral growth. The additional variable of ground temperature would be recorded to explain potential discrepancies (i.e confounding variables) in the data (see Convey et al. 2000).

Treatments (with multiple locations per treatment)

1. Within colony
2. Border of colony (i.e depression zone)
3. Downstream (i.e. fluvially) of colony
4. Non-downstream (i.e upstream) of colony

Measurements

1. Moisture content
2. Organic carbon content
3. Sulphur, P_2O_5,CaO, copper, zinc, selenium, strontium, barium, fluorine content (sensu Liguang et al. 2014)
4. Heavy metal concentrations

5. Proximity of treatment site from closest penguin colony
6. Density of penguins
7. Floral density (species richness, type, physical density)
8. Floral species
9. Ground temperature (at a consistent depth)

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